ment may be configured as a dual purpose sense and excitation transducer, capable of directly participating in impulse reconstruction processes. In configurations in which the excitation transducer does not participate directly in impulse reconstruction, the excitation transducer may be used to provide enhanced features and functionality to a touch sensitive apparatus.

[**0043**] The excitation transducer may indirectly participate in impulse reconstruction processes by, for example, facilitating a plate calibration procedure by which relative or absolute dimensions of the touch sensitive plate may be determined. The plate dimension data is information used to perform impulse reconstruction according to embodiments of the present invention. By way of further example, the dispersion relation of the touch sensitive plate may be determined using techniques involving the excitation transducer. Another capability is directed to pickup sensor calibration, in which differences in sensor phase response are determined, and corrections are made to the measured bending wave signals to accommodate such differences in sensor phase response.

[**0044**] Other capabilities involving the use of an excitation transducer include enhanced lift-off detection, improved sensitivity to light touches, and improved wake-on-touch functionality. Details of various methodologies directed to lift-off detection and improved sensitivity to light touches are described in commonly owned co-pending U.S. patent application entitled "Touch Sensing with Touch Down and Lift Off Sensitivity," filed concurrently herewith under Attorney Docket 59377US002 and incorporated herein by reference. Details of various wake-on-touch methodologies are disclosed in U.S. patent application Ser. No. 10/683,342, filed Oct. 10, 2003, which is incorporated herein by reference.

[**0045**] A touch sensing apparatus implemented in accordance with the present invention may incorporate one or more of the features, structures, methods, or combinations thereof described herein. It is intended that such a device or method need not include all of the features and functions described herein, but may be implemented to include selected features and functions that, in combination, provide for unique structures and/or functionality. For example, and as discussed previously, the impulse reconstruction techniques described herein may be implemented in touch sensing apparatuses of varying configurations, including those that employ pickup sensors and no excitation transducer and those that employ both pickup sensors and at least one excitation transducer.

[**0046**] In vibration sensing touch input devices that include piezoelectric sensors, for example, vibrations propagating in the plane of the touch panel plate stress the piezoelectric sensors, causing a detectable voltage drop across the sensor. The signal received can be caused by a vibration resulting directly from the impact of a direct touch input or the input of energy with a trace (friction), or by a touch input influencing an existing vibration, for example by attenuation of the vibration. The signal received can also be caused by an unintended touch input, such as a touch input resulting from user handling or mishandling of the touch input device, or from environmental sources external to, but sensed by, the touch input device.

[**0047**] According to one touch sensing approach, upon receiving a signal indicative of a direct touch, for example, the differential times at which the same signal is received at each of the sensors can be used to deduce the location of the touch input. When the propagation medium is a dispersive medium, the vibration wave packet, which is composed of multiple frequencies, becomes spread out and attenuated as it propagates, making interpretation of the signal difficult. As such, it has been proposed to convert the received signals so they can be interpreted as if they were propagated in a non-dispersive medium. Such a technique is particularly suited to systems that detect bending wave vibrations.

[**0048**] Techniques for addressing vibration wave packet dispersion and producing representative signals corrected for such dispersion are disclosed in International Publications WO 2003/005292 and WO 01/48684; U.S. patent application Ser. No. 09/746,405 filed Dec. 26, 2000; U.S. Provisional Application 60/432,024 filed Dec. 10, 2002; and in commonly owned U.S. patent application Ser. No. 10/440,650, each of which is incorporated herein by reference.

[**0049**] The term bending wave vibration refers to an excitation, for example by the contact, which imparts some out of plane displacement to a member capable to supporting bending wave vibrations. Many materials bend, some with pure bending with a perfect square root dispersion relation and some with a mixture of pure and shear bending. The dispersion relation describes the dependence of the in-plane velocity of the waves on the frequency of the waves.

[**0050**] For purposes of enhancing an understanding of vibration wave packet dispersion and producing representative signals corrected for such dispersion, reference is made to **FIGS. 1**_a_-**1**_d_. **FIG. 1**_a_ shows an impulse in an ideal medium with a square root dispersion relation and demonstrates that a dispersive medium does not preserve the waveshape of an impulse. The outgoing wave **60** is evident at time t=0 and the echo signal **62** is spread out over time, which makes a determination of an exact contact position problematic.

[**0051**] In a non-dispersive medium such as air, a periodic variation of the frequency response is characteristic of a reflection, and is often referred to as comb filtering. Physically, the periodic variation in the frequency response derives from the number of wavelengths that fit between the source and the reflector. As the frequency is increased and the number of wavelengths fitting in this space increases, the interference of the reflected wave with the outgoing wave oscillates between constructive and destructive.

[**0052**] Calculating the Fourier transform of the dispersive impulse response of **FIG. 1**_a_ produces the frequency response shown in **FIG. 1**_b_. The frequency response is non-periodic and the periodic variation with wavelength translates to a variation in frequency that gets slower with increasing frequency. This is a consequence of the square root dispersion in which the wavelength is proportional to the square root of the inverse of frequency. The effect of the panel on the frequency response is therefore to stretch the response as a function of frequency according to the panel dispersion. Consequently, a correction for the panel dispersion may be applied by applying the inverse stretch in the frequency domain, thus restoring the periodicity present in the non-dispersive case.

[**0053**] By warping the frequency axis with the inverse of the panel dispersion, **FIG. 1**_b_ may be transformed into the